

What is claimed is:

1. A method for producing a polymer waveguide on a substrate, the method comprising the steps of:

a) providing a substrate and then

b) conducting (i) or (ii) or (iii):

(i) coating a layer of a liquid, photosensitive buffer composition onto the substrate; then deoxygenating the buffer layer under the conditions of vacuum, purging with inert gas, or a combination of vacuum and purging with inert gas; overall exposing the deoxygenated buffer composition to sufficient actinic radiation to only partially polymerize the buffer composition to a level below a substantially full curing of the buffer composition;

(ii) coating a layer of a liquid, photosensitive underclad composition onto the substrate; then deoxygenating the underclad layer under the conditions of vacuum, purging with inert gas, or a combination of vacuum and purging with inert gas; overall exposing the deoxygenated underclad composition to sufficient actinic radiation to only partially polymerize the underclad composition to a level below a substantially full curing of the underclad composition;

(iii) coating a layer of a liquid, photosensitive buffer composition onto the substrate; then deoxygenating the buffer layer under the conditions of vacuum, purging with inert gas, or a combination of vacuum and purging with inert gas; overall exposing the deoxygenated buffer composition to sufficient actinic radiation to only partially polymerize the buffer composition to a level below a substantially full curing of the buffer composition; followed by coating a layer of a liquid, photosensitive underclad composition onto the buffer

layer; then deoxygenating the underclad layer under the conditions of vacuum, purging with inert gas, or a combination of vacuum and purging with inert gas; overall exposing the deoxygenated underclad composition to sufficient actinic radiation to only partially polymerize the underclad composition to a level below a substantially full curing of the clad composition; and

c) coating a layer of a liquid, photosensitive core composition onto a surface of the buffer layer or the clad layer; then deoxygenating the core layer under the conditions of vacuum, purging with inert gas, or a combination of vacuum and purging with inert gas and then covering the core layer with an inert gas atmosphere;

d) positioning a photomask having a waveguide pattern, at a level above, substantially parallel to, and either in contact with the core layer or not in contact with the core layer, and then imagewise exposing the photosensitive core composition through said photomask, to sufficient actinic radiation to only partially polymerize the core composition to a level below a substantially full curing of the core composition but beyond the gel point of the core composition, while maintaining the core coated substrate in an inert gas atmosphere;

e) developing the exposed core composition layer to remove the non-image areas while not removing the image areas;

f) coating a layer of a liquid, photosensitive overclad composition over at least the image areas of the core composition; then deoxygenating the overclad layer and all underlying layers under conditions of vacuum, purging with inert gas, or a combination of vacuum and purging with inert gas; overall exposing the overclad composition,

under an inert gas atmosphere, to sufficient actinic radiation to substantially fully cure, the buffer composition layer if present, the clad composition layer if present, the core composition layer and the overclad composition layer.

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2. The method of claim 1 where step (i) is conducted.

3. The method of claim 1 where step (ii) is conducted.

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4. The method of claim 1 where step (iii) is conducted.

5. The method of claim 1 wherein step (i) further comprises removing an edge portion of the buffer layer prior to actinic radiation exposure of the buffer layer; step (ii) further comprises removing an edge portion of the underclad layer prior to actinic radiation exposure of the clad layer; and step (iii) further comprises removing an edge portion of the buffer layer prior to actinic radiation exposure of the buffer layer and removing an edge portion of the underclad layer prior to actinic radiation exposure of the underclad layer.

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6. The method of claim 1 wherein step (c) further comprises removing an edge portion of the core layer prior to step (d).

7. The method of claim 1 further comprising applying an adhesion promoting tie composition layer onto the surface of the substrate prior to step (b).

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8. The method of claim 1 further comprising applying a photosensitive adhesion promoting tie composition layer onto the surface of the substrate prior to step (b).

9. The method of claim 1 further comprising applying an adhesion promoting tie composition layer onto the surface of the substrate; removing an edge portion of the tie composition layer, and partially curing the remaining portion of the tie layer prior to step (b).
10. The method of claim 1 further comprising applying a photopolymerizable adhesion promoting tie composition layer onto a surface of the substrate; removing an edge portion of the tie composition layer, and partially curing the remaining portion of the tie layer by exposure to sufficient actinic radiation to only partially polymerize the tie composition to a level below a substantially full curing of the tie composition but beyond the gel point of the tie composition, prior to step (b).
11. The method of claim 1 wherein the photomask contacts the surface of the core layer.
12. The method of claim 1 wherein the photomask does not contact the surface of the core layer.
13. The method of claim 1 further comprising the subsequent step of thermally annealing the coated substrate.
14. The method of claim 1 wherein the refractive index of the substantially fully cured, polymerized buffer composition is from about 0.75 % to about 3 % less than the refractive index of the substantially fully cured, polymerized core; and wherein the refractive index of the substantially fully cured, polymerized

underclad composition is from about 0.3 % to about 1.5 % less than the refractive index of the substantially fully cured, polymerized core.

15. The method of claim 1 wherein the inert gas comprises nitrogen.

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16. The method of claim 1 wherein the actinic radiation comprises ultraviolet radiation.

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17. The method of claim 1 wherein the photomask is positioned from about 5  $\mu\text{m}$  to about 20  $\mu\text{m}$  above the core composition layer.

18. The method of claim 1 wherein development step is conducted with a fluorinated solvent.

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19. The method of claim 1 wherein a surface of the substrate has been subjected to a preliminary cleaning step.

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20. The method of claim 1 wherein a surface of the substrate has been subjected to a preliminary cleaning step and then primed with an acrylate functionalized chloro- or alkoxy- silane compound.

21. The method of claim 1 wherein the deoxygenating is conducted such that the level of ambient oxygen is about 2% or less.

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22. The method of claim 1 wherein the deoxygenating is conducted such that the level of ambient oxygen is about 0.1% or less.

23. The method of claim 1 wherein the step of exposing the buffer composition and the underclad composition to actinic radiation is conducted such that the buffer composition and the underclad composition are exposed to sufficient actinic radiation to polymerize the compositions to at least the gel point, but  
5 exposed to less actinic radiation than that amount above which additional actinic radiation exposure would cause no effective change in the refractive index of the composition.

24. The method of claim 1 wherein the buffer composition comprises one or more  
10 fluorinated (meth)acrylate monomers having a functionality of equal to or greater than 2, wherein the refractive index of the substantially fully cured, polymerized buffer composition is from about 0.75 % to about 3 % less than the refractive index of the substantially fully cured, polymerized core.

25. The method of claim 1 wherein the underclad composition comprises one or  
15 more fluorinated (meth)acrylate monomers having a functionality of equal to or greater than 2, wherein the refractive index of the substantially fully cured, polymerized underclad composition is from about 0.3 % to about 1.5 % less than the refractive index of the substantially fully cured, polymerized core.

26 The method of claim 1 wherein the core composition comprises one or more  
20 fluorinated (meth)acrylate monomers having a functionality of equal to or greater than 2.

27. The method of claim 1 wherein the overclad composition comprises one or  
25 more fluorinated (meth)acrylate monomers having a functionality of equal to or greater than 2, wherein the refractive index of the substantially fully cured,

polymerized underclad composition is from about 0.3 % to about 1.5 % less than the refractive index of the substantially fully cured, polymerized core.

28. The method of claim 1 further comprising the step of removing at least a portion of the underclad layer or buffer layer from the area adjacent to, along and symmetrical with the core, prior to the step of coating the layer of a liquid, photosensitive overclad composition over at least the image areas of the core composition.

29. A polymeric waveguide which comprises

- a substrate;
- a polymeric patterned core on the substrate; and
- a polymeric buffer layer, or a polymeric underclad layer, or sequentially both a polymeric buffer layer and a polymeric underclad layer between the substrate and the polymeric patterned core; wherein the polymeric buffer layer, or polymeric underclad layer or both the polymeric buffer layer and a polymeric underclad layer have a pattern which are along and symmetrical with the core.

30. The polymeric waveguide of claim 29 wherein the polymeric buffer layer, or polymeric underclad layer or both the polymeric buffer layer and a polymeric underclad layer have a lower level which is at least about 0.5  $\mu\text{m}$  below the lowest level of the core.